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UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

REINFORCED DRY RUBBLE MASONRY DAMS - GENET

From

REVUE DES EUX ET FORÊTS

Tome LXXIII IXe Série - 33° Année

No. 2 - Fevrier 1935

Translation by

E. L. Hamilton

Assistant Silviculturist

January 1936

California Forest & Range Experiment Station

San Dimas Experimental Forest

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REINFORCED DRY RUBBLE MASONRY

THE REBOGET SYSTEM

General

We have had occasion since 1929 to help with experimentation and development of a new method of constructing works of dry rubble masonry reinforced by metallic braces or frames, whose special arrangement is of general interest.

The use of this system of bracing called "The Reboget System" gives dry rubble masonry structures a particular resistance and allows the use of material of smaller size than ordinary, supplanting almost entirely all sorts of dry masonry.

This interesting invention seems especially adapted to the construction of checks in ravines and barriers of any size in torrential streams.

Description of the system

Essentially the system consists in setting against the facing of a dry masonry structure, a mettalic gridiron or panel which is solidly anchored upstream by means of a series of heavy wire cables fastened at the other end to that portion of the reinforcing called the "anchorage", which is ballasted with large rocks. (Fig. 1).

The gridwork or panel a-c, the anchorage e-f, the connecting cables and the rockwork are placed simultaneously (and later

[illegible] [illegible]

[illegible]

[illegible]

REINFORCED DRY RUBBLE

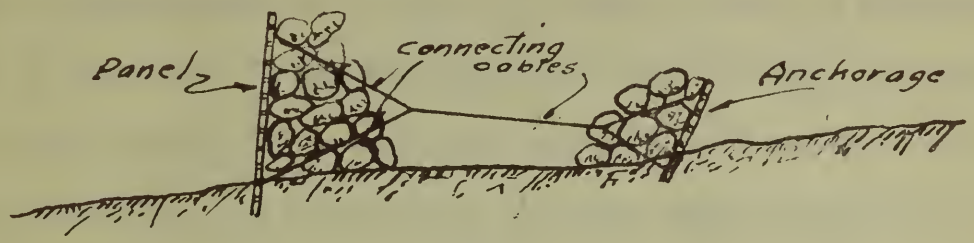


FIG. 1

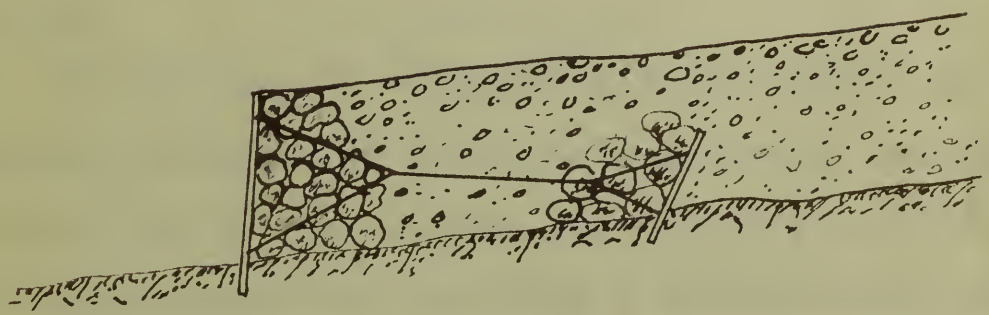


FIG. 2.

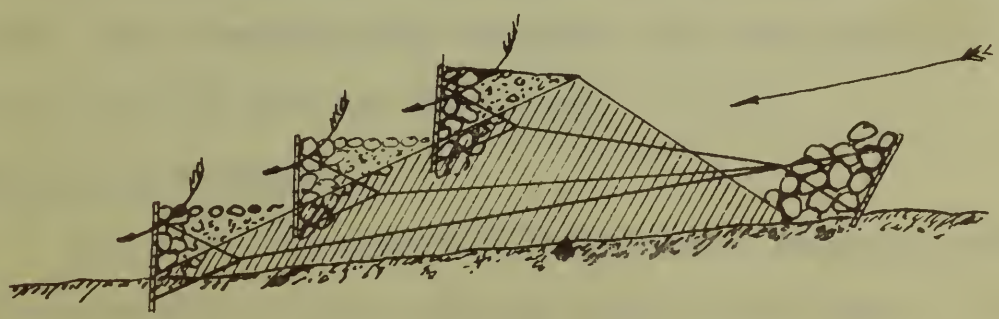


FIG. 3.

the whole is completed by the deposition of an alluvial fill).

It is evidently the framework, grids, cables and anchors which constitutes most of the strength of the structure. Once deposition starts, whether it may consist of terracing in a ravine or actual sedimentation in a river, the whole becomes a reinforced monolith in which are buried the cables and the anchors, and experience has shown that the framework does not move even under the action of strong currents. All one has to do under these conditions is to give the dry rubble wall a rough outline and to use material of smaller size than usual with the sole reservation that it cannot pass through the grid.

The advantages of reinforced dry rubble over ordinary dry rubble may be compared to the great advantage which reinforced concrete has over cut stone masonry. The reinforced dry rubble as with concrete permits the utilization of smaller material and simplifies the construction.

One may, in many cases, back or line the grid with the largest rock, completing the embankment with the balance of the material derived from the excavations.

Construction by benches

One of the principal characteristics of "Reboget" works is the construction of dams, weirs and other similar works in steps or benches. This bench construction is due to the fact that the grids are necessarily limited in height. In actual practice, an average panel height of 75 cm to 1 meter (2½ to 3¼ feet) is shown to be quite satisfactory. A network of greater height than this

REINFORCED DRY RUBBLE

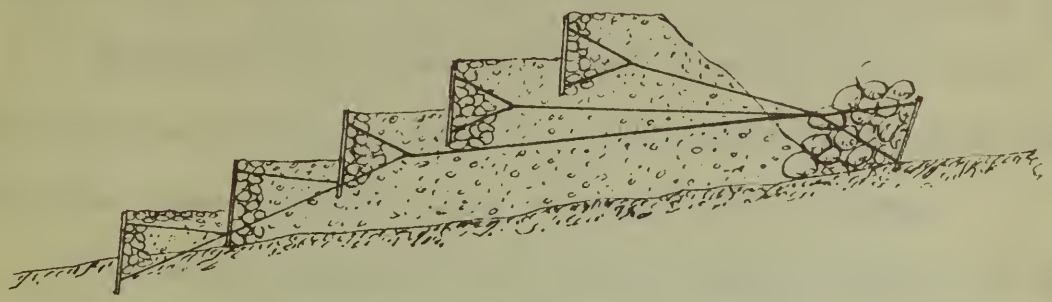


FIG. 4

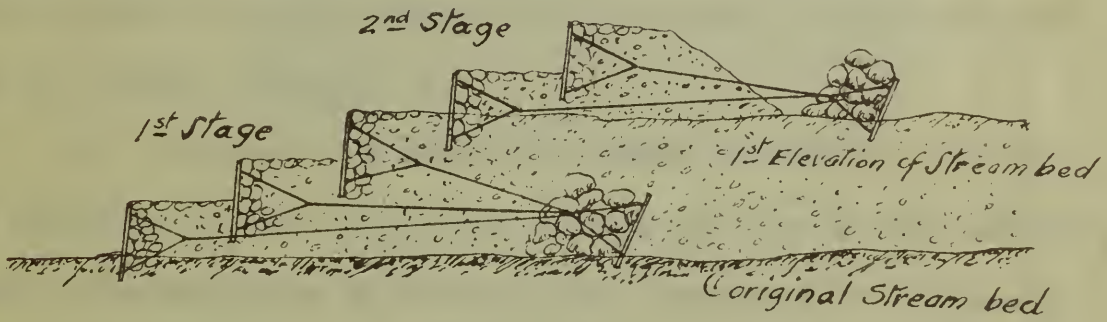


FIG. 5.

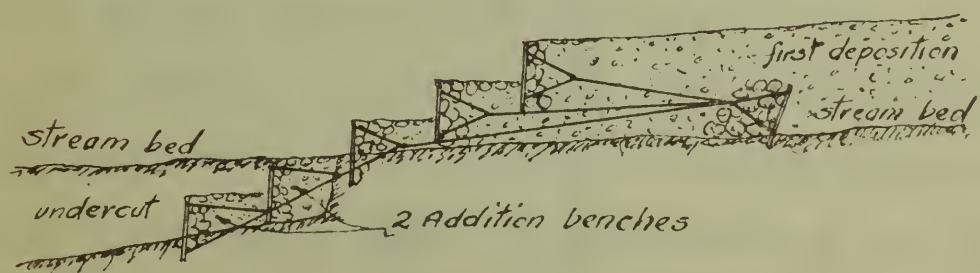


FIG. 6.

above the streambed would naturally cause inconvenience in placing the material and further, the moments of gravity and resistance would be hard to overcome (the strain on the uprights requiring heavier steel; number and complication of horizontal cables, etc.)

Structures of a fixed height may be stabilized without difficulty by building successive benches which will result in a structure whose equilibrium may be expressed as follows:

The hatched section (Fig. 3) is in static equilibrium by itself, the use of the framework being reduced

1. to maintain the equilibrium of the dotted portion, which evidently is assured, no matter how high the structure may be, by a light framework

2. to hinder the water which seeps through the structure, as indicated by the arrows, from washing out the filling material, which is accomplished by the dry rubble supported by the panels.

The top and the bottom of each bench may be tied by the cables directly to the anchorage (Fig. 3) or to the base of the panel of the next higher bench at the same place where, in turn, its anchor cables are attached (Fig. 4, the 3 lower benches). This latter disposition of cables gives an indirect but continuous connection to the anchors through the lower branches of the cables for the upstream panels.

Evidently it is not advantageous to build structures made up of more than three or four benches at the most, as this would raise too high an embankment. On the other hand, if natural silting is allowed to take place structures may be built of any height desired. In spite of their height these works are nevertheless

A. - Small dams of reinforced dry rubble masonry, showing construction in stages.

C. and D. - Barrier 90 meters (295') long of reinforced dry rubble masonry in a torrential river of the Basses-Alpes (The anchorage level is shown at bb).

solid, due to the subdivision of the strains of the entire assembly.

Further, in the case of dams, the overflow is broken up in such a manner that the risk of undercutting is considerably lessened. Besides, it may be noted that new benches may be added to existing structures either on the downstream or the upstream side.

The section shown in Fig. 3 applies either to weirs or dams, but the system may be used to build other sorts of structures such as retaining walls or longitudinal dikes.

Constitution of the panels of the framework

The panels are made of 18 x 3 mm (3/4 x 1/8") flat iron uprights 75 cm (2½') to 1 m (3¼') high, spaced 30 cm (12") apart. This flat iron is drilled and is traversed by 5 or 6 mm (3/16") round bars spaced vertically 8 to 10 cm (3 to 4").

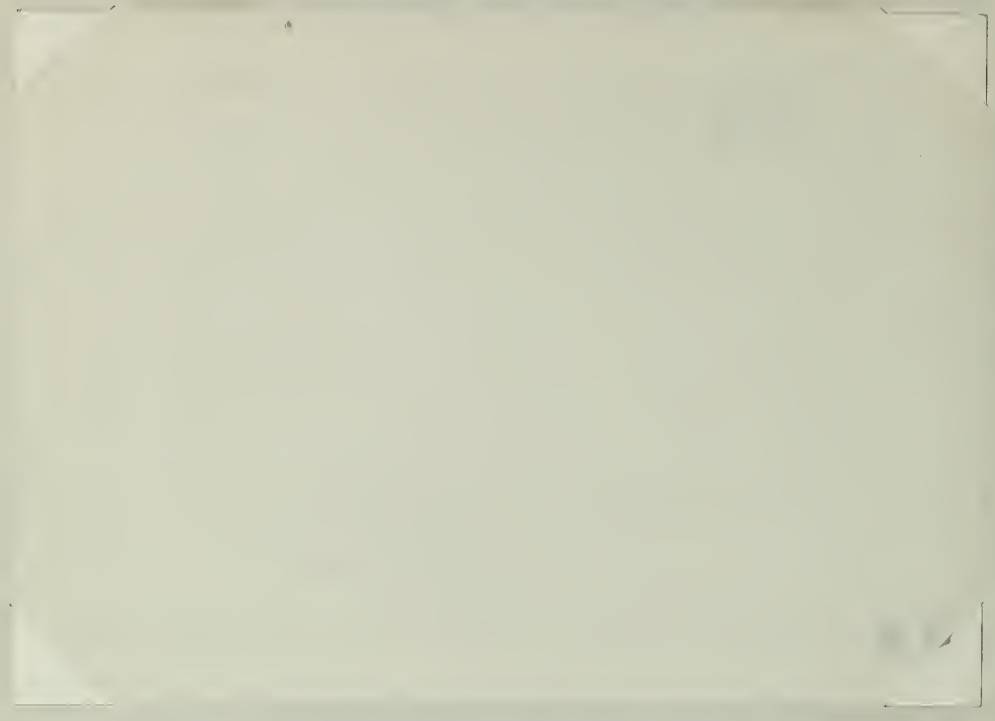
The cables are attached to the uprights at both top and bottom.

It has been found through trial that this type of framework which is ideal for structures protected from heavy battering by large boulders (as for instance, barriers of any size) was, on the other hand too weak to be used in structures which may be called on to withstand the shock of large boulders.

Accordingly, during the course of various trials, the size of both the flat and the round iron was increased and in certain cases Tee bars were substituted for the flat iron, at least partially.

B. - Small dams of reinforced loose rock showing construction in stages.

E. - Small check dam of reinforced loose rock, after having been silted up.



One must not lose sight of the fact that it is useless to increase excessively the size of the steel for this will augment greatly the cost of the structure, one of whose chief advantages is its cheapness. Moreover, any other form of panel which may seem more advantageous, may be substituted for this one, for the main feature of the "Reboget" system is the connecting cable and the anchorage. The static thrust on the base and the face and eventually the thrust on the abutments of a masonry or concrete structure is replaced here by a dynamic thrust on the connecting cables fastened to an anchor which is stabilized by a mass of heavy boulders.

Whence the stress, which is laid on the importance of the strength of the system of connectors and anchors.

The construction of the panel lends itself to various modifications.

Further the writer as well as the inventor, has considered the use of expanded metal as well as solid corrugated sheets, but no trial of either of these has as yet been made. A priori, we feel a preference for the original style of panel.

The main objection which is usually made to the use of metal is its tendency to rust.

Exception has been taken to metallic circles. This has been remedied by the use of galvanized wire.

We have adopted the same material for the wires of the connecting cables and various other tie wires, but we have not tried anything else for the uprights and the horizontal members of the

panels.

In the first place red lead or grey "anti-rust" paints give appreciable protection and are not expensive.

Experiments have been tried with copper bearing steel (notably Apso) which seem interesting.

Other trials will be made using other metals which are rustless in varying degrees (such as Durapso, A.P.S. 5, Wendel copper bearing steel, etc.) This is merely mentioned in passing and no further mention will be made of them, as the experiments are either in preparation or are too recent to permit the drawing of conclusions.

We have also considered using Armco pure iron which is free of carbon and very slightly subject to rusting; but it has the great defect of not being readily available on the market and of costing much more than ordinary iron.

However, undue importance must not be attached to the question of the indefinite life of metal and we must consider that we are not demanding from these structures any greater length of life than may be expected from regular masonry works. They are destined to give temporary results such as depositions of soil and rectification of channels which cannot be achieved definitely, as foresters well know, except by the introduction of vegetation. Frameworks of galvanized iron or of special more or less rust-proof iron may last 20 years at least, a period sufficient to permit the soil deposit to be fixed by vegetation.

Comparison with wire mesh cribbing

Structures made of reinforced dry rubble masonry may be con-

people.

In the first place real land or just "adjacent" parking give opportunity protection and are not expensive.

Communities have been faced with another [illegible] (Antarctic Apex) major area [illegible].

Other friends will be made using other media which are mentioned in varying degrees [name] as Darrigan, A.T.T. S, [name] copper bearing steel, etc.] Note it metals available in existing and do further research will be made of them, as the economics are either in development or are too remote to permit the drawing of conclusions.

To these also commercial noting areas have been added [illegible] type of carbon and very slightly subject to reaction; but it has the first before it not being readily available as the matter was of costing much more than ordinary iron.

However, modern improvements must not be attended to the [illegible] tion of the indefinite life of metal and we must consider that by are not departing from these structures and greater length of life [illegible] may be expected from regular necessary entry. They are destined to give temporary results such as [illegible] of all most practicable of economic which cannot be accurate definitely, as forecasts well apart, except by the introduction of variation. Thousands of [illegible] iron or of special duty or less trouble type may last 20 years at least, a rather sufficient to permit all the well demands to be fixed or replaced.

Corrosion [illegible] with deep pitting:

Protective coats of [illegible] necessary may be com-

pared to others formed of wire mesh cribs.

It is a fact that to date metallic cribs comprise the only use of metal in the construction of rustic works. Also it is interesting to compare the advantages and disadvantages of one system with the other.

It is recalled that a crib (gabion) consists of a sort of box usually rectangular in shape, made of heavy galvanized wire mesh, which is filled with rock, without any other binding medium. These cribs are made in various sizes, which permits the assembly of rustic masonry works of all shapes and dimensions.

The principal advantage of structures made up of these cribs is that they are at once solid and homogenous yet have some flexibility.

By this flexibility cribs are adapted to torrential flows which would cause the ruin of a rigid structure made of other material.

After these works have silted up a compact mass is formed which the force of the water cannot dislodge or carry away.

However, in order to give a structure composed of cribs, a sufficient stability, one must lay them lengthwise and place them on sills or flat cribs, thus forming a jutting out base, which as it settles is designed to fill up, to some extent, the space caused by undercutting. All this leads to structures of a size relatively large which are, by this fact, great consumers of rock. This necessitates greater expenditure for labor in their construction.

If the cribs are flexible, this flexibility may cause too

frequently, deformations which are not premissible in such structures.

The presence of horizontal partitions will cause the structure to sink in a body when settling takes place.

Reinforced dry rubble acts differently. With it there is a sort of internal flexibility, settling exerts only a slight strain on the connecting cables and produces but slight displacements of the grids, which remain vertical. This maintains the equilibrium of the structure and gives it a better appearance. This advantage is particularly noticeable in ravines where structures built of cribs are washed from their foundations, roll in every direction and really are more harmful than useful.

In any case, since the connecting cables are buried in the silt, they are not exposed to the scouring action of bed load or shocks from boulders, a circumstance which assures a longer life to Reboget structures than to check dams built up with wire mesh cribs.

In practice, however, it is recommended that the better features of the wire mesh crib and the Reboget systems be combined.

In the case of barriers for example it is interesting to top them off by cribs placed lengthwise of the axis of the structure and which so placed will follow to the best advantage the reduction in grade of the stream bed, frequently very noticeable, at the end of a weir and gives added safety from currents striking the structure in an unforeseen direction.

Dams of reinforced dry rubble (Photo X)

The forester who is engaged in the work of controlling

ravines may use the Reboget system for the construction of works in stages or benches, to which it is particularly applicable (Photos A and B).

If the ravine contains rock which is large enough to cut and is suitable for the purpose, the best suggestion is to build dry rubble structures; but if the rock is smaller, they are not so advisable. In the case outlined, reinforced dry rubble is distinctly preferable to ordinary dry rubble. Structures made of the latter will be loosely constructed, have a relatively short life, and will be comparatively heavy.

If a forest which is in need of thinning is near the ravine which is to be treated (this is frequently the case in the course of replanting) small structures may be constructed using timber cribbing, broken stone and wire. These works, however, are neither very stable or long lived. On the whole, they use considerable wood and stone and are expensive.

When, however, the rock is small or of poor quality and there is no timber in the vicinity of the site, then the Reboget system is called on for service.

Small Reboget dams are very slightly subject to deformation and present an excellent appearance due to the disposition of the framework whereby the face of the dam must conform to its vertical placement.

The metal is protected throughout from the wear which might result from the friction of drift material.

Experience has shown that Reboget dams resist perfectly the

undercutting at the foot of the lower framework.

As we have mentioned before, there is nothing to hinder the construction of additional benches at the toe of the structure (Fig. 6) except that this operation will add to the work the impression of badly contrived patchwork.

One finds in the dry Alps numerous little ravines, cutting into the clays, which carry large quantities of small sized gravel which they deposit in the villages or on roads.

These ravines do not have a very great discharge and do not cause very serious erosion but they are annoying by reason of their deposits which always accumulate at the same places and cannot reach the river on account of the thickening of the deposits due to the disappearance of the water into the soil down through the gravels. Such ravines are a source of considerable expense to highway commissioners and could be easily controlled by creating one or more debris basins in their drainage in conveniently chosen spots.

These debris storages can be constructed advantageously by means of a series of Reboget dams, built successively one after the other as check or debris dams.

Reinforced dry rubble masonry in rivers.

Reboget frameworks may be used equally well in the construction of protective works in torrential rivers. A number of this type of barriers has been built under the direction of M. Reynaud, engineer of the T.P.E. in the torrential river Asse, left tributary of the Durance, which is subject to dangerous floods. We have

closely followed the construction of one of these structures which is 90 meters (295') long which is designed to protect the arable land around Saint Julien d'Asse.

The structure has withstood several heavy floods without any damage in that portion which was made of reinforced dry rubble. Only the crest which was made of gabions has been subject to some slight damage (Photos C and D).

The cross-section of this structure has been shown in Fig. 3. Here the anchorage which consists of a panel similar to the main vertical grid, has been merely laid on the ground inclined upstream and ballasted with heavy boulders.

Economy of the system

One of the advantages of the Reboget reinforced dry masonry system is the smallness of its net cost.

The trials made in the Asse Valley (weirs and dams) have shown a saving of about 50% compared with works of the same usefulness made of ordinary masonry or of metallic cribs.

Under these circumstances, considering their life and solidity, the cost of Reboget structures is very advantageous especially where rock is scarce, small or of poor quality,

CONCLUSION

The application of this interesting invention in which we have been very much interested since its first trial, is to a considerable extent the work of our friend M. Reynaud, T.P.E. engineer at Montelimar.

It has been patented in France (No. 674209) and in various

foreign countries.

A company to operate under this patent is being formed, which expects to continue the experiments set forth, particularly concerning a rustless metal which is best adapted to the required conditions (working, life, net cost, etc.)

As to the use which foresters may make of it, this reinforced dry rubble seems to us, by reason of its moderate cost, called upon to render appreciable service in reforestation for the correction of secondary ravines which do not carry heavy boulders and where ordinary dry rubble would give poor results.

E. Genet
Inspector of Forests and Water